SEPTIC TANK SAND FILTER SYSTEM FOR TREATMENT OF DOMESTIC SEWAGE

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Ministry of the Environment
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SEPTIC TANK - SAND FILTER SYSTEMS

FOR

TREATMENT OF DOMESTIC SEWAGE

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ABSTRACT

In continuation of a previous study (Domestic Sewage Treatment by Underdrained Filter Systems, Pub. No. 53) four additional filters containing media of different physical and/or chemical characteristics were installed in May 1973 to determine their capability for the treatment of private waste, in particular for reducing the phosphorus content. The media used were sand, red mud, crushed limestone or natural soil.

The efficiency of removal of biochemical oxygen demand (BOD_5) and suspended solids from the waste was 96% or more. The nitrogen compounds were oxidized to nitrates, showing only traces of free ammonia and organic nitrogen generally less than 1.5 mg/1.

For removal of phosphorus, red mud continued to be relatively more effective as compared to the other additives. The efficiency of 89% during the first year was more than 62% even after five years of operation. Crushed limestone (effective size 0.24 mm) initially showed an efficiency of phosphorus removal of 89%. This, however, started declining rapidly after three months operation and was 48.4% by the end of the second year.

The filters containing natural soil were able to reduce phosphorus content by 68% during the first year, but dropped to 42.5% in the second year of operation. The efficiency of removal depended on the percentage of silt and clay in the compostion of the natural soils used.

1.0 GENERAL

In unsewered areas where conditions for the installation of a conventional tile field for the disposal of septic tank effluent are not favourable, a sand filter may provide a satisfactory alternative method of treatment. In order to determine the effectiveness of filter media of different physical characteristics for this purpose, experimental facilities for the treatment of domestic waste from staff residences were constructed at Whitby Ontario Hospital in 1969. Underdrained filters constructed of commonly available sands in Ontario were put into operation in September of that year. The description of the plant and results of the investigation for the period September 1969 to May 1973 were presented in M.O.E. Publication Report No. 53.

The study was continued and this report is for the period May 1973 to September 1975, after which some of the filters have been operated with sewage at progressively higher rates than the 49 and 73 $l/m^2/d$ (1 and 1.5 gpd/ft^2) previously and herein reported, to determine the capability for treatment by those filters before any failure due to overloading occurs.

The physical characteristics of the filter media used initially in this investigation are given in Table 1. The filter beds each containing 76 cm of filter media were loaded with septic tank effluent at the rate of 49 l/m^2/day. After four months operation filter media with effective size (D_{10}) of 0.14 mm and 0.19 mm clogged at the sewage-sand interface and the material in those two beds was replaced by sand with effective size (D_{10}) of 0.24 mm and Uniformity Coefficient (Cu) of 3.9. In one of these renewed beds, "red mud" a waste by-product of bauxite purification containing oxides of calcium, aluminum and iron, mixed with

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NOTE: 1 ft. = 30.48 cm

1 gpd/ft^2 = 49 $l/m^2/d$

a portion of sand, was used to observe its effect in the removal of phosphates from the waste.

All filter beds operated satisfactorily, reducing Biochemical Oxygen Demand (BOD_5) and Suspended Solids (SS) by 90% or more when loaded at 49 l/m^2/day and 73 l/m^2/day as trickle feed or as siphon discharge. The efficiency of phosphorus removal by the various filter media without chemical additives was an average 30%. The filter media containing red mud, however, showed an efficiency of 88.9%, 79.4% and 72.3% during the first, second and third year of operation respectively.

At this stage the investigations were extended to include other filter media for determining their capability of removing phosphorus, when used as such, or when mixed with natural soil or material of different physical and/or chemical characteristics. The building was extended for accommodating storage tanks and measuring equipment, etc. and four additional filter beds, similar in size to the existing ones, two each on the north and south of the buildings, were installed.

The plan for location of the filter beds and characteristics of filter media are given in Fig. 1 and Table 2 respectively. The schematic flow sheet for the installation is shown in Fig. 2.

2.0 INSTALLATION

Four new filter beds were installed by the side of the existing beds, above ground in wooden boxes, with the necessary inlet and outlet connections for the distribution and collector pipes.

2.1 Filter Bed No. 7

Sand D_{10} = 0.24 mm Cu = 3.9 and red mud

Filter bed no. 7 (Fig. 4) was constructed similar to filter bed No. 1 except that (a) the layer of sand mixed with red mud was placed above the gravel and increased from 20 cm to 38 cm depth and (b) the mixture contained 10% red mud and 90% sand instead of 4% red mud and 96% sand. The chemical analysis of red mud is given in Table 3. The grain size analysis of sand is shown in Fig. 3.

2.2 Filter Bed No. 8

Sand D_{10} = 0.24 mm Cu = 3.9

Limestone D_{10} = 0.29 mm Cu = 18.3

In bed No. 8 limestone 50%, mixed with sand 50%, was placed as a layer 38 cm deep above the gravel similar to that for bed No. 7. This was covered by 38 cm of sand and the installation was completed in the usual way by installing distributor pipes in the gravel above sand as shown in Fig. 6. The grain size analysis of limestone is given in Fig. 5.

2.3 Filter Bed No. 9

Natural Soil

For bed No. 9, natural soil obtained from a construction site was used as the filter media. The soil could be classified as silt and sand, some clay and traces of gravel. The grain size distribution is shown in Fig. 7. The filter was installed with the usual distribution and collector pipes and the gravel. Fig. 8 gives a view of the completed bed.

2.4 Filter Bed No. 10

Sand and Natural Soil

For the construction of Filter bed No. 10, natural soil from 76 cm depth was excavated from the rear of the experimental station and was mixed with 50% of the same sand as used in beds 7 and 8. A layer of this mixture 38 cm deep was placed above the gravel and

the bed completed as usual. The grain size distribution of the excavated soil which was classified as silt and clay with traces of sand is shown in Fig. 9 and a section of the filter in Fig. 10.

3.0 OPERATION

On the completion of alterations to the building and installation of the four additional filter beds, the plant was put into operation on May 15, 1973. The sewage loading rate of 49 $l/m^2/day$, after over one year of operation, was increased to 73 $l/m^2/day$ from July 1974. The sewage inflow pattern during this investigation period was conventional trickle flow, periodic discharge eight times per day i.e. every three hours and again as trickle flow:

(i)	trickle flow at 49 $l/m^2/day$	May 15, 1973 to July 1, 1974
(ii)	trickle flow at 73 $l/m^2/day$	July 2, 1974 to Oct. 7, 1974
(iii)	periodic discharge at 73 $l/m^2/day$	Oct. 8, 1974 to May 21, 1975
(iv)	trickle flow at 73 $l/m^2/day$	May 22, 1975 to Sept. 3, 1975

The septic tank was pumped out on June 22, 1973 and April 24, 1974. The sewage pump in the septic tank broke down on June 22, 1973 and was repaired. It continued however to cause problems and had to be replaced by a new pump on September 17, 1974. The analyses of septic tank effluent is given in Table 4.

3.1 Filter Beds No. 1, 2, 3, 4, 5, and 6 (Tables 5 to 10)

Filter beds No. 1, 2, 3, and 4 were kept in operation for the entire period under report without any major problem. Filter beds No. 5 and 6, however, were operated for part of the time when sewage was available after meeting the required needs for the other beds i.e. No. 1 to 4 and No. 7 to 10.

Filter bed No. 5 developed a leak in the plastic liner to the extent that the outflow was not sufficient to provide adequate samples for analyses, most of the effluent being absorbed in the soil under the filter. The operation of this system consequently was discontinued and only average values of some of the parameters are given in the tables.

For filter beds No. 1, 2, 3, and 4 in 85% of the samples of the effluents, the BOD_5 and suspended solids were equal to or less than 3.8 mg/l and 6.6 mg/l respectively. For bed 6 the corresponding values were up to 10 mg/l each.

Filter bed No. 1 containing "red mud" produced effluent in which the phosphorus concentration in 85% of the samples was equal to or less than 4.5 mg/l P and 5.3 mg/l P, during the 4th and the 5th year of operation respectively; the corresponding values in septic tank effluent were 13.9 mg/l P and 14.2 mg/l P. This gave phosphorus removal efficiency of 67.4% and 62.7%. In the earlier three consecutive years from the start the efficiencies were 88.9%, 79.4% and 72.3%. For the other beds, without additives, there were some variations in the phosphorus residuals but these were not significant for phosphorus removal. The residuals, were in the range of 7.2 mg/l to 9.8 mg/l.

The free ammonia in 85% of the samples was 0.36 mg/l or less excepting for filter No. 6 which took several weeks for stabilization of nitrogenous compounds before approaching 1.1 mg/l. The concentration of organic nitrogen was 1.5 mg/l or less for beds No. 1 to 4 and 1.1 mg/l for bed No. 6. The corresponding nitrite was 0.27 mg/l N and 0.4 mg/l N. The nitrate content of 19.0 mg/l N was the lowest for bed No. 6 as compared to the other beds which was in the range of 34.5 mg/l N to 41.0 mg/l N.

The methylene blue active substances (MBAS) of up to 12.5 mg/l in the septic tank waste effluent in 85% of the samples were reduced to 0.5 mg/l or less by passage of the waste through the filters. This showed an efficiency for removal of MBAS of 96% or more.

There was a large reduction in the total and fecal coliforms in the effluents from all filters. The filter bed No. 6, however, had the highest numbers of total coliforms of 25,000 MPN/100 ml as compared to the other beds. Fecal coliforms of less than 100 MPN/100 ml in 85% of the samples were found in the effluent from bed No. 1 containing red mud in the filter media. In septic tank effluent the total and fecal coliform, were up to 80 x 10^6 and 3.5 x 10^6 respectively.

The trends of the concentrations of the parameters tested in the effluent from these filter beds were not different from that observed during more than three previous years of operation.

3.2 Filter Bed No. 7 (Table 11) Sand and Red Mud

The filter bed No. 7 produced an effluent with BOD_5 and suspended solids in 50% of the samples to be equal to or less than 1.4 mg/l and 3.1 mg/l respectively. In 85% of the samples the corresponding values were equal to or less than 3.5 mg/l and 6.1 mg/l. The values for phosphorus in 85% of the samples during first and second year of operation were equal to or less than 1.8 mg/l and 2.5 mg/l P respectively as compared to 13.9 mg/l P and 14.2 mg/l P in the septic tank effluent. This, when compared with septic tank effluent, showed phosphorus reduction of 87.3% and 82.3% in the two consecutive years. The capacity for removal of phosphorus in bed No. 7 due to the relatively greater quantity of red mud is expected to be higher than in bed No. 1 before exhaustion of the red mud.

The free ammonia, organic nitrogen, nitrite and nitrate in 85% of the samples were up to 0.48 mg/l, 1.00 mg/l, 0.12 mg/l and 42.0 mg/l respectively.

The residual MBAS in the effluent was 0.22 mg/l or less in 85% of the samples.

Fecal Coliform removal was relatively more than in the other filter beds e.g. those containing limestone or natural soil, the effluent values being 130 MPN/100 ml or less.

3.3 Filter Bed No. 8 (Table 12) Sand and Limestone

The BOD and suspended solids in 50% of the samples were equal to or less than 1.1 mg/l and 3.9 mg/l respectively. In 85% of the samples the corresponding values were 2.4 mg/l and 6.4 mg/l.

During the initial three months of operation, the phosphorus reduction through the bed was 89%. This efficiency, however, dropped rapidly and by the end of the first year it was 69.9%. On continued operation for another year it reached a low of 48.4% when the concentration of phosphorus in the effluent was 7.3 mg/l P.

The effluent showed 0.2 mg/l free ammonia, 0.9 mg/l organic nitrogen and 35.3 mg/l nitrate as maximum for 85% of the samples. The nitrite content was 0.05 mg/l or less.

The MBAS in 85% of the samples was 0.28 mg/l or less. The maximum fecal coliform count of 1450 MPN/100 ml in 85% of the samples for this filter of sand and limestone was not significantly different from filter No. 10 containing natural soil and sand.

3.4 Filter Bed No. 9 (Table 13) Natural Soil

Filter bed No. 9 operated intermittently. It produced an effluent with BOD and suspended solids of 6.5 mg/l and 8.5 mg/l or less respectively

in 85% of the samples. There had been, however, repeated problems due to leakage, breakup of pipes, formation of cracks in the filter media, and channeling of the waste. This was indicated by deterioration in the quality of the effluent.

The concentrations of phosphorus in the effluent during first and second year of operation were 4.8 mg/1 and 7.4 mg/1 P or less, giving efficiency of phosphorus removal of 65.6% and 47.5% in the two consecutive years of operation.

Due to frequent channeling of the waste through the filter media and some interruptions, the complete stabilization of the nitrogen compounds could not always be attained. The free ammonia, nitrite, organic nitrogen were 1.40 mg/1, 0.99 mg/1 and 1.10 mg/1 respectively. For the same reason the reduction in total and fecal coliform was relatively lower as compared to other beds. The counts were 110,000 and 7500 MPN/100 ml respectively. However, during the short periods when there was no channeling this system treated the waste satisfactorily and the values for the various parameters mentioned earlier were much lower and within the range observed for the other filters under this investigation.

3.5 Filter Bed No. 10 (Table 14) Sand and Natural Soil

The filter No. 10 operated during the period under report without any problems of channeling such as occurred in bed No. 9 containing only natural soil. The effluent was of a quality that did not show much fluctuation. The BOD and Suspended Solids concentrations in 85% of the samples were equal to or less than 2.7 mg/1 and 4.8 mg/1 respectively. The corresponding values for phosphorus were 4.4 mg/1 P and 6.4 mg/1 P, giving an efficiency of removal of 68.8% and 55.1% during the two years of operation.

The nitrogenous compounds in the waste were oxidized satisfactorily in this filter as indicated by low concentrations of free ammonia, nitrite and organic nitrogen, 0.41 mg/l, 0.15 mg/l and 1.09 mg/l respectively and by the high nitrate content of 42.5 mg/l or less in 85% of the samples.

The MBAS concentration in the effluent was 0.3 mg/l and the coliform reduction was similar to that by other sand filters.

4.0 DISCUSSION

The pattern of septic tank effluent feed into the beds, as conventional trickle flow or as periodic dishcarge, similar to that usually obtained by a siphon or a pump operation in field installations, and at loading rates of 49-73 l/m^2/day, did not indicate any significant change in the quality of the effluent from the filters except some increase in suspended solids in bed 6 effluent. For comparison, values for the various paramaters for beds No. 1 - 10 and for the septic tank effluent are given in Tables 15 to 21.

4.1 BOD_5 (Table 15)

The effluent from all filter beds under normal operation had BOD_5 values of up to 4.4 mg/l in 50% of the samples. In 85% of the samples the values in general were less than 6.5 mg/l except for bed No. 6 (D_{10} = 2.5mm) which had corresponding value of 9.3 mg/l. The efficiency of BOD_5 removal was more than 96%.

Filter No. 9 containing natural soil had a tendency to form cracks in the beds resulting in channeling of the waste. Under these conditions quality of the effluent from this filter deteriorated, showing BOD_5 values of more than 15 mg/l.

4.2 Suspended Solids (Table 15)

In 50% of the samples the suspended solids were equal to or less than 5.5 mg/l and in 85% of the samples these did not exceed 10 mg/l. They were in the range of 4.7 mg/l to 6.6 mg/l excepting for beds No. 6 and No. 9 for which the values were 9.8 mg/l and 8.5 mg/l respectively. The suspended solids removal efficiency for all the beds was greater than 96%.

4.3 Free Ammonia, Nitrite, Organic Nitrogen and Nitrates (Tables 16 & 17)

The concentration of free ammonia and organic nitrogen in 85% of the samples of septic tank effluent were 37.4 mg/l and 21.9 mg/l respectively. In the treated effluent from all beds excepting bed No. 9, which often did not operate satisfactorily due to channeling of the waste, concentrations in 50% of the samples were in the range of 0.1 mg/l to 0.4 mg/l for ammonia and 0.61 mg/l to 0.82 mg/l for organic nitrogen. In 85% of the samples the corresponding range was 0.15 mg/l to 1.1 mg/l for ammonia and 0.64 to 1.55 mg/l for organic nitrogen. The efficiency of treatment in each case was 95% or more.

The nitrite content always was very low, 0.08 mg/l or less in 50% of the samples and not exceeding 0.4 mg/l in 85% of the samples. The relatively higher values were for bed No. 6 containing pea gravel as filter media.

For filter bed No. 9, before channeling of the waste occurred, values for the various parameters were within the range as observed for the other filter beds. Afterwards, however, relatively higher values indicated that the nitrogenous compounds in this bed did not approach complete oxidation. The concentrations were up to 1.47 mg/l free ammonia, 0.99 mg/l nitrite and 2.7 mg/l organic nitrogen.

As expected, with relatively higher residuals of free ammonia and organic nitrogen in the effluent from filter beds No. 6 and No. 9, the corresponding nitrate content was lower. The values in 85% of the samples were 19.0 mg/l and 26.0 mg/l or less. For the other eight beds, however, these were in the range of 34.5 mg/l to 42.5 mg/l (N).

4.4 Phosphorus (Table 18)

The phosphorus removal efficiency by the old filters No. 2 to No. 6 without chemical additives did not show any significant change from the previous years and was on average in the range of 30-46%. For the other new beds, however, there were variations from one year to the next as well as with the nature of additives used in the filter media.

4.4.1 RED MUD

Red mud greatly reduced phosphate content in the effluents from bed No. 1 and bed No. 7. The efficiency of removal was highest during first year of operation and continued to decrease with time.

During the initial period of twelve months from the start, the efficiencies for beds No. 1 and No. 7 were 88.9% and 87.3% respectively. During the second year of operation the corresponding values for the two beds were 79.9% and 82.3%. The percentage efficiencies for the two filter beds No. 1 and No. 7 with the number of years of operation were as follows:

% Efficiency of Phosphorus Removal

No. of years of Operation	Filter bed No. 1	Filter bed No. 7
1	88.9	87.3
2	79.9	82.2
3	72.5	-
4	67.4	-
5	62.7	-

Filter bed No. 7 contained a 38 cm layer of 10% red mud in sand as compared to 20 cm of 4% red mud in bed No 1. The drop in efficiency for phosphorus removal in bed No. 7 during two years operation appeared to be at a lower rate. It would however require longer period of time to confirm this trend as well as to determine the extent of difference in the phosphorus removal capacity of the two beds.

4.4.2 LIMESTONE

The presence of limestone in bed No. 8 reduced the phosphate content of the incoming waste during the initial period of operation of the system when the efficiency of removal was 89%. This efficiency however, was very short lived, approximately three months, at which time it began declining. It was 69.9% and 48.4% or less in 85% of the samples during first and second years of operation. It is possible that the surfaces of the limestone became coated with some material which caused reduction in reactivity with the waste containing phosphates.

4.4.3 NATURAL SOIL

The natural soil used in the study in bed No. 9, classified as silt and sand, some clay and traces of gravel, reduced phosphorus relatively more than the filters containing only sand. The removal during first and second years of operation was 65.6% and 42.5% respectively. Apparently it depended upon the amount of clay in the filter media, as in filter No. 10, containing relatively more clay, the phosphorus removal efficiency was slightly higher, 68.8% and 55.1% during the two years of operation.

4.5 COD (Table No. 19)

The values for COD as expected, followed the same trend as those of BOD. These were on the average less than 30 mg/1 and in 85% of the samples equal to or less than 55 mg/1.

4.6 MBAS (Table No. 20)

The filters reduced concentration of MBAS to values in the range of 0.12 mg/1 to 0.47 mg/1 in 85% of the samples. The corresponding value for septic tank effluent was 12.5 mg/1. This gave an efficiency of removal of 96 to 99%.

4.7 Total Solids (Table No. 19)

The total solids in the effluents were in the range of 580 mg/1 to 750 mg/1 in 50% of the samples. In 85% of the samples these were 650 to 940 mg/1.

4.8 Coliforms (Table No. 21)

The effluents from all filter beds indicated a great reduction in total and fecal coliforms as compared to that from the septic tank. There could however be found no correlation between physical characteristics of the filter media and the number of coliforms removal. Excluding bed No. 9 the total coliform in the effluents, considering 85% of the samples, were in the range of 1,250 to 25,000 MPN/100 ml while the septic tank effluent had 80 x 10^6 MPN/100 ml. The corresponding values for fecal coliform were <100 - 2200 MPN/100 ml and 3,500 x 10^3 MPN/100 ml.

5.0 SUMMARY

1. Filter beds containing filter media, Effective Size (D_{10}) in the range of 0.24 mm to 2.5 mm and Uniformity Coefficient (Cu) of 4.1 or less, treated septic tank effluent when loaded at the rate of 49 $1/m^2$/day or 73 $1/m^2$/day satisfactorily during almost six years operation. They produced effluents with BOD_5 and Suspended Solids less than 5.5 mg/1 in 50% of the samples. In 85% of the samples the values were 9.8 mg/1 or less. The relatively higher values were for the filter bed containing pea gravel effective size (D_{10}) of 2.5 mm.

2. Free Ammonia and organic nitrogen were oxidized by the filter beds, the effluent showing nitrate in the range of 19 mg/l to 42.5 mg/l. The effluent from the filter containing pea gravel had 19 mg/l nitrate and also showed relatively higher residuals of free ammonia, equal to or less than 1.1 mg/l in 85% of the samples. In the effluents from other filters, free ammonia was in the range of 0.15 mg/l to 0.48 mg/l and organic nitrogen 0.64 mg/l to 1.5 mg/l. In the filter bed containing natural soil, and showing a tendency to channel the waste, complete stabilization of nitrogen compounds could not always be achieved.

3. The removal of phosphorus by sand was in the range of 30-46%. In case of natural soil containing silt and sand and some clay, removal of P during the first year of operation was 65.6% but declined to 42.5% in the second year. In the filter containing relatively more clay the efficiencies were slightly higher, 68.8% and 55.1% during the first two consecutive years of operation. Crushed limestone mixed with sand appeared promising, giving P removal efficiency of 89% at the start of the system but after approximately three months operation in efficiency decreased rapidly and was 69.9% and 48.4% in the ramaining period of the first and in the second year respectively.

Red mud continued to remove phosphorus more consistently as compared to the other additives in the filter beds. During operations the efficiency of 88.9% in the first year was reduced to 62.7% in five years in steps of 5% to 7% per year. With relatively large amounts of red mud in the sand mixture, however, the loss in efficiency with increased use could be lower, thereby offering a possibility of longer useful life of the system.

4. The soils alone or with additives were capable of reducing MBAS by 96% to 99%. The concentrations in the effluents from the filter beds and the septic tank were equal to or less than 0.5 mg/l and 12.5 mg/l respectively in 85% of the samples.

5. All filter beds were effective in reducing total and fecal coliforms. The number of total coliforms (MPN/100 ml) in the effluents from the filter beds, excluding No. 9 (in which channeling of the waste occurred) were 1250 to 25,000 and in the septic tank more than 80×10^6. The corresponding numbers for fecal coliforms were <100 to 2200 and 3.5×10^6. Filter beds containing pea gravel (D_{10} = 2.5 mm) as filter media had relatively higher counts; filter beds containing sand mixed with red mud showed fecal coliforms 130 or less MPN/100 ml.

CONCLUSIONS AND RECOMMENDATIONS

1. Filters using a 76 cm deep bed of sand as filter medium with effective grain size in the range of 0.24 mm to 2.50 mm and Uniformity Coefficient of less than 4.5 at a waste loading rate of up to 73 l/m^2/day will treat septic tank effluent with a reduction of biochemical oxygen demand and suspended solids by 96% and of phosphorus by 30% or more.

2. Sand mixed with red mud or crushed limestone or natural soil containing clay and silt will reduce phosphorus content of the waste by up to 90% depending on the nature and quantity of the additives in the sand.

3. For single family dwellings in the areas where local conditions are not favourable for a conventional tile field installation, a septic tank and sand filter of not less than 15 m^2 surface area and 75 cm deep is a recommended alternative for waste treatment providing;

   a) The filter is sized for the daily sewage flow so as not to exceed a loading rate of 75 l m^2/day (1.5 gpd/ft^2)

   b) Arrangements for the construction, and the inspection of construction, can be made to ensure that the design requirements of this type of leaching bed are obtained under field conditions.

TABLE I

CHARACTERISTICS OF FILTER MEDIA

1969-71

Filter Bed No.	Filter Media	Effective Size D_{10} mm	Uniformity Coefficient Cu
1	Concrete Sand	0.19	4.4
2	Block Sand	0.30	4.1
3	Foundry Slag	0.60	2.7
4	Asphalt Sand	0.15	2.8
5	Fine Gravel with Sand	1.0	2.1
6	Pea Gravel	2.5	1.2

TABLE 2

CHARACTERISTICS OF FILTER MEDIA
1971-75

Filter Bed No.	Filter Media
1	Medium Sand* and red mud
2	Block Sand D_{10} = 0.30 mm; Cu = 4.1
3	Foundry Slag D_{10} = 0.60 mm; Cu = 2.7
4	Medium Sand*
5	Fine Gravel with Sand D_{10} = 1.0 mm; Cu = 2.1
6	Pea Gravel D_{10} = 2.5 mm; Cu = 1.2
7	Medium Sand* and red mud
8	Medium Sand* and limestone D_{10} = 0.24 mm; Cu = 18.3
9	Natural Soil - 55% silt and clay, 38% Sand, 7% Gravel
10	Medium Sand* and soil - 92% silt and clay, 8% Sand

* Effective size (D_{10}) = 0.24 mm
Uniformity Coefficient (Cu) = 3.9

TABLE 3

ANALYSIS OF "RED MUD"

JUNE 5, 1973

	Percentage
SiO_2	14.80
CaO	4.92
Na_2O	18.38
Al_2O_3	36.54
Fe_2O_3	24.24

TABLE 4

EFFLUENT QUALITY

SEPTIC TANK

	VALUES*		
	% of Time equal to or less than		
	15%	50%	85%
BOD	109	185	315
COD	220	360	610
Susp. Solids	61	130	285
Total Solids	605	850	1040
Free Ammonia (N)	9.8	23.6	37.4
Organic Nitrogen (N)	9.4	15.6	21.9
Nitrite (N)	< 0.01	0.02	0.05
Nitrate (N)	< 0.1	0.1	0.3
MBAS	4.2	7.3	12.5
Total Phosphates (P)			
1973-74	4.6	9.3	13.9
1974-75	5.1	9.7	14.2
Total Coliform MPN/100 ml	3.4×10^6	32×10^6	84×10^6
Fecal Coliform MPN/100 ml	8×10^3	510×10^3	3500×10^3

* All values except coliforms in mg/l

TABLE 5

EFFLUENT QUALITY

FILTER BED NO. 1

Medium Sand and Red Mud

	VALUES *		
	% of Time equal to or less than		
	15%	50%	85%
BOD	<1.0	<1.0	2.2
COD	<20	<20	30
Susp. Solids	<1.0	2.0	5.9
Total Solids	640	750	860
Free Ammonia (N)	<0.1	0.1	0.24
Organic Nitrogen (N)	0.25	0.52	1.06
Nitrite (N)	<0.01	<0.02	0.08
Nitrate (N)	10.5	18.2	34.5
MBAS	0.10	0.10	0.12
Total Phosphates (P)			
1973-74	1.9	3.3	4.5
1974-75	1.9	3.6	5.3
Total Coliform MPN/100 ml	<15	200	2200
Fecal Coliform MPN/100 ml	<10	<100	<100

* All values except coliforms in mg/l

TABLE 6

EFFLUENT QUALITY

FILTER BED NO. 2

Block Sand

D_{10} = 0.30 mm

Cu = 4.1

	VALUES* % of Time equal to or less than		
	15%	50%	85%
BOD	<1.0	1.0	2.4
COD	<20	<20	25
Susp. Solids	1.3	2.3	4.7
Total Solids	660	745	930
Free Ammonia (N)	<0.1	0.1	0.16
Organic Nitrogen (N)	0.13	0.59	0.64
Nitrite (N)	0.01	0.02	0.11
Nitrate (N)	7.9	17.0	37.0
MBAS	0.1	0.18	0.34
Total Phosphates (P)			
1973-74	2.2	4.1	7.8
1974-75	2.0	4.9	7.9
Total Coliform MPN/100 ml	<100	310	1250
Fecal Coliform MPN/100 ml	<10	<100	400

* All values except coliforms in mg/l

TABLE 7

EFFLUENT QUALITY

FILTER BED NO. 3

Foundry Slag

D_{10} = 0.60 mm

Cu = 2.7

	VALUES* % of Time equal to or less than		
	15%	50%	85%
BOD	<1.0	1.4	3.8
COD	<20	<20	35
Susp. Solids	<1.0	3.6	6.6
Total Solids	570	690	815
Free Ammonia (N)	<0.1	0.1	0.15
Organic Nitrogen (N)	0.31	0.72	1.55
Nitrite (N)	0.01	<0.02	0.08
Nitrate (N)	9.8	18.5	36.2
MBAS	0.1	0.15	0.36
Total Phosphates (P)			
1973-74	1.9	4.5	7.4
1974-75	2.7	5.5	8.3
Total Coliform MPN/100 ml	1800	5800	18,000
Fecal Coliform MPN/100 ml	<100	300	1300

* All values except coliforms in mg/l

TABLE 8

EFFLUENT QUALITY — Medium Sand

FILTER BED NO. 4 — D_{10} = 0.24 mm

Cu = 3.9

	VALUES* % of Time equal to or less than		
	15%	50%	85%
BOD	<1.0	1.5	3.2
COD	<20	<20	30
Susp. Solids	<1.0	2.3	5.3
Total Solids	595	730	895
Free Ammonia (N)	<0.1	0.15	0.36
Organic Nitrogen (N)	0.40	0.66	1.14
Nitrite (N)	<0.01	0.03	0.27
Nitrate (N)	8.5	19.0	41.0
MBAS	0.1	0.21	0.37
Total Phosphates (P)			
1973-74	1.8	4.7	7.5
1974-75	1.7	5.0	8.2
Total Coliform MPN/100 ml	<100	360	1900
Fecal Coliform MPN/100 ml	<100	<100	380

* All values except coliforms in mg/l

TABLE 9

EFFLUENT QUALITY

FILTER BED NO. 5

Sand with Fine Gravel

D_{10} = 1.0 mm

C_u = 2.1

Values * (average)

BOD	4.3
COD	30
Susp. Solids	4.9
Total Solids	617
MBAS	0.4
Total Phosphates (P)	6.8
Total Coliforms MPN/100 ml	1810
Fecal Coliforms MPN/100 ml	167

* All values except coliforms in mg/l

TABLE 10

EFFLUENT QUALITY — Pea Gravel

FILTER BED NO. 6 — D_{10} = 2.5 mm

Cu = 1.2

	VALUES * % of Time equal to or less than		
	15%	50%	85%
BOD	2.5	4.4	9.3
COD	30	40	50
Susp. Solids	2.1	5.5	9.8
Total Solids	480	610	740
Free Ammonia (N)	0.1	0.4	1.1
Organic Nitrogen (N)	0.17	0.48	1.1
Nitrite (N)	< 0.02	0.08	0.4
Nitrate (N)	4.4	9.1	19.0
MBAS	0.1	0.18	0.40
Total Phosphates (P)			
1973-74	4.5	6.3	9.8
1974-75			
Total Coliform MPN/100 ml	200	2,200	25,000
Fecal Coliform MPN/100 ml	<100	240	2,200

* All values except coliforms in mg/l

TABLE 11

EFFLUENT QUALITY

FILTER BED NO. 7

Medium Sand and Red Mud

	VALUES* % of Time equal to or less than		
	15%	50%	85%
BOD	<1.0	1.4	3.5
COD	<20	<20	35
Susp. Solids	<1.0	3.1	6.1
Total Solids	620	755	940
Free Ammonia (N)	<0.1	<0.1	0.48
Organic Nitrogen (N)	0.35	0.55	1.00
Nitrite (N)	<0.01	0.02	0.12
Nitrate (N)	8.5	18.4	42.0
MBAS	0.1	0.14	0.22
Total Phosphates (P)			
1973-74	0.5	1.1	1.8
1974-75	0.9	1.7	2.5
Total Coliform MPN/100 ml	<100	500	5400
Fecal Coliform MPN/100 ml	<10	<100	130

* All values except coliforms in mg/l

TABLE 12

EFFLUENT QUALITY

FILTER BED NO. 8

Medium Sand
and
Crushed Lime Stone

	VALUES* % of Time equal to or less than		
	15%	50%	85%
BOD	<1.0	1.1	2.4
COD	<20	<20	25
Susp. Solids	1.4	3.9	6.4
Total Solids	635	750	890
Free Ammonia (N)	<0.1	0.1	0.20
Organic Nitrogen (N)	0.36	0.52	0.90
Nitrite (N)	<0.01	<0.02	0.05
Nitrate (N)	8.0	16.7	35.5
MBAS	0.1	0.15	0.28
Total Phosphates (P)			
1973-74	0.3	2.5	4.3
1974-75	1.7	4.5	7.3
Total Coliform MPN/100 ml	300	1200	9000
Fecal Coliform MPN/100 ml	<100	235	1450

* All values except coliforms in mg/l

TABLE 13

EFFLUENT QUALITY

FILTER BED NO. 9 Natural Soil

	VALUES* % of Time equal to or less than		
	15%	50%	85%
BOD	1.2	3.6	6.5
COD	<20	25	55
Susp. Solids	<1.0	4.6	8.5
Total Solids	575	660	755
Free Ammonia (N)	<0.1	0.4	1.4
Organic Nitrogen (N)	0.4	1.0	1.1
Nitrite (N)	0.03	0.22	0.99
Nitrate (N)	4.3	10.5	26.0
MBAS	0.1	0.18	0.47
Total Phosphates (P)			
1973-74	0.7	2.8	4.8
1974-75	1.8	4.6	7.4
Total Coliform MPN/100 ml	<100	4,000	110,000
Fecal Coliform MPN/100 ml	<100	800	7,500

* All values except coliforms in mg/l

TABLE 14

EFFLUENT QUALITY

FILTER BED NO. 10

Medium Sand
and
Natural Soil

	VALUES*		
	% of Time equal to or less than		
	15%	50%	85%
BOD	<1.0	1.2	2.7
COD	<20	<20	30
Susp. Solids	1.1	2.9	4.8
Total Solids	635	735	845
Free Ammonia (N)	<0.1	0.1	0.41
Organic Nitrogen (N)	0.22	0.59	1.10
Nitrite (N)	<0.01	0.03	0.15
Nitrate (N)	8.4	19.0	42.5
MBAS	0.1	0.14	0.30
Total Phosphates (P)			
1973-74	1.0	2.7	4.4
1974-75	3.7	5.1	6.4
Total Coliform MPN/100 ml	1300	4700	10,700
Fecal Coliform MPN/100 ml	<100	120	1250

* All values except coliforms in mg/l

TABLE 15

COMPARISON OF EFFLUENT QUALITY

BOD_5 and
Suspended Solids

Filter Bed No.	BOD_5 VALUES* % of Time Equal to or less than			Suspended Solids VALUES* % of Time Equal to or less than		
	15%	50%	85%	15%	50%	85%
1	<1.0	<1.0	2.2	<1.0	2.0	5.9
2	<1.0	<1.0	2.4	1.3	2.3	4.7
3	<1.0	1.4	3.8	<1.0	3.6	6.6
4	<1.0	1.5	3.2	<1.0	2.3	5.3
5	-	4.3**	-	-	4.9	-
6	2.5	4.4	9.3	2.1	5.5	9.8
7	<1.0	1.4	3.5	<1.0	3.1	6.1
8	<1.0	1.1	2.4	1.4	3.9	6.4
9	1.2	3.6	6.5	<1.0	4.6	8.5
10	<1.0	1.2	2.7	1.1	2.9	4.8
Septic Tank	109	185	315	61	130	285

* All values in mg/l ** Average Values

TABLE 16

COMPARISON OF EFFLUENT QUALITY

Free Ammonia (N) and

Organic Nitrogen (N)

Filter Bed No.	Free Ammonia (N) VALUES* % of Time Equal to or less than			Organic Nitrogen (N) VALUES* % of Time Equal to or less than		
	15%	50%	85%	15%	50%	85%
1	<0.1	0.1	0.24	0.25	0.52	1.06
2	<0.1	0.1	0.16	0.13	0.59	0.64
3	<0.1	0.1	0.15	0.31	0.72	1.55
4	<0.1	0.15	0.36	0.40	0.66	1.14
5	-	-	-	-	-	-
6	0.1	0.4	1.10	0.17	0.48	1.10
7	<0.1	<0.1	0.48	0.35	0.55	1.0
8	<0.1	0.1	0.20	0.36	0.52	0.90
9	<0.1	0.4	1.40	0.4	1.0	1.10
10	<0.1	1.0	0.41	0.22	0.59	1.10
Septic Tank	9.8	23.6	37.4	9.4	15.6	21.9

* All values in mg/l

TABLE 17

COMPARISON OF EFFLUENT QUALITY

Nitrate (N) and

Nitrite (N)

Filter Bed No.	Nitrate (N) VALUES* % of Time Equal to or less than			Nitrite (N) VALUES* % of Time Equal to or less than		
	15%	50%	85%	15%	50%	85%
1	10.5	18.2	34.5	<0.01	<0.02	0.08
2	7.9	17.0	37.0	0.01	<0.02	0.11
3	9.8	18.5	36.2	0.01	<0.02	0.08
4	8.5	19.0	41.0	<0.01	0.03	0.27
5	-	-	-	-	-	-
6	4.4	9.1	19.0	<0.02	0.08	0.4
7	8.5	18.4	42	0.01	<0.02	0.12
8	8.0	16.7	35.5	<0.01	<0.02	0.05
9	4.3	10.5	26.0	0.03	0.22	0.99
10	8.4	19.0	42.5	<0.01	0.03	0.15
Septic Tank	<0.1	0.1	0.3	<0.01	0.02	0.05

* All values in mg/l

TABLE 18

COMPARISON OF EFFLUENT QUALITY

Phosphorus P

Filter Bed No.	Phosphorus P 1973-74 VALUES* % of Time Equal to or less than			Phosphorus P 1974-75 VALUES* % of Time Equal to or less than		
	15%	50%	85%	15%	50%	85%
1	1.9	3.3	4.5	1.9	3.6	5.3
2	2.2	4.1	7.8	2.0	4.9	7.9
3	1.9	4.5	7.2	2.7	5.5	8.3
4	1.8	4.7	7.5	1.7	5.0	8.2
5	-	6.8**	-	-	-	-
6	4.5	6.3	9.8	-	-	-
7	0.5	1.1	1.8	0.9	1.7	2.5
8	0.3	2.5	4.3	1.7	4.5	7.3
9	0.7	2.8	4.8	1.8	4.6	7.4
10	1.0	2.7	4.4	3.7	5.1	6.4
Septic Tank	4.6	9.3	13.9	5.1	9.7	14.2

* All values in mg/l ** Average Values

TABLE 19

COMPARISON OF EFFLUENT QUALITY

COD and Total Solids

Filter Bed No.	COD VALUES* % of Time Equal to or less than			Total Solids VALUES* % of Time Equal to or less than		
	15%	50%	85%	15%	50%	85%
1	<20	<20	30	640	750	860
2	<20	<20	25	660	745	930
3	<20	<20	35	570	690	815
4	<20	<20	30	595	730	895
5	-	30**	-	-	617**	-
6	30	40	50	480	610	740
7	<20	<20	35	620	755	940
8	<20	<20	25	635	750	890
9	<20	25	55	575	660	755
10	<20	<20	30	635	735	845
Septic Tank	220	360	610	605	850	1040

* All values in mg/l　　** Average Values

TABLE 20

COMPARISON OF EFFLUENT QUALITY

MBAS

Filter Bed No.	MBAS VALUES* % of Time Equal to or less than		
	15%	50%	85%
1	0.1	.10	.12
2	.1	.18	.34
3	.1	.15	.36
4	.1	.21	.37
5	-	.04**	-
6	.1	.18	.40
7	.1	.14	.22
8	.1	.15	.28
9	.1	.18	.47
10	.1	.14	.30
Septic Tank	4.2	7.3	12.5

* all values in mg/1 ** Average values

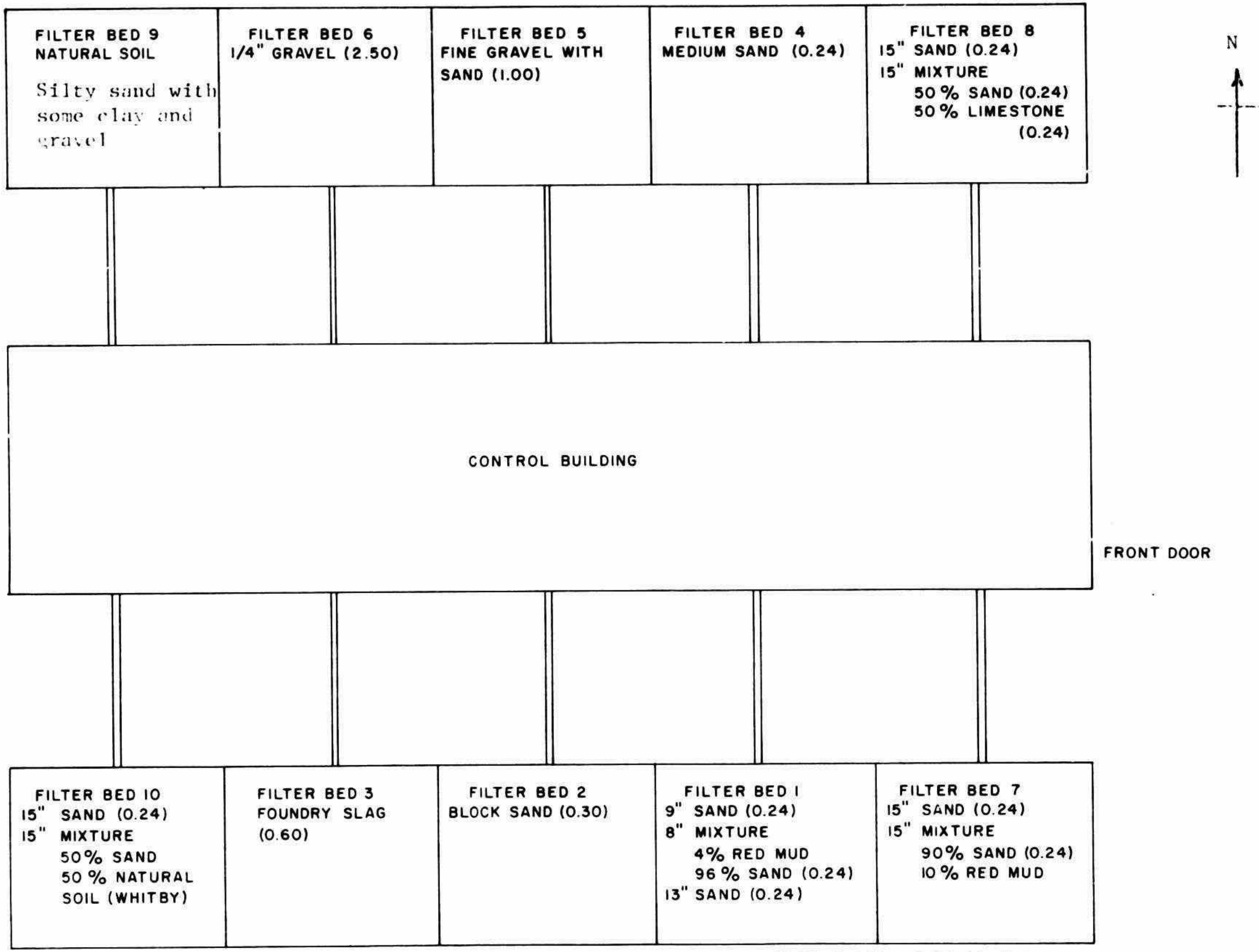
TABLE 21

COMPARISON OF EFFLUENT QUALITY

Total Coliforms and
Fecal Coliforms

Filter Bed No.	Total Coliforms VALUES* % of Time Equal to or less than			Fecal Coliforms VALUES* % of Time Equal to or less than		
	15%	50%	85%	15%	50%	85%
1	<15	200	2,200	<10	<100	<100
2	<100	310	1,250	<10	<100	400
3	1,800	5,800	18,000	<100	300	1,300
4	<100	360	1,900	<100	<100	380
5	-	1,810**	-	-	167**	-
6	200	2,200	25,000	<100	240	2,200
7	<100	500	5,400	<10	<100	130
8	300	1,200	9,000	<100	235	1,450
9	<100	4,000	110,000	<100	800	7,500
10	1,300	4,700	10,700	<100	120	1,250
Septic Tank	3.4×10^6	32×10^6	$80^+ \times 10^6$	8×10^3	510×10^3	3.5×10^6

* All values in mg/1   ** Average Values



FIGURES IN BRACKETS ARE THE EFFECTIVE GRAIN SIZE (D_{10}) IN mm.

FIG. 1 ARRANGEMENT OF FILTER BEDS

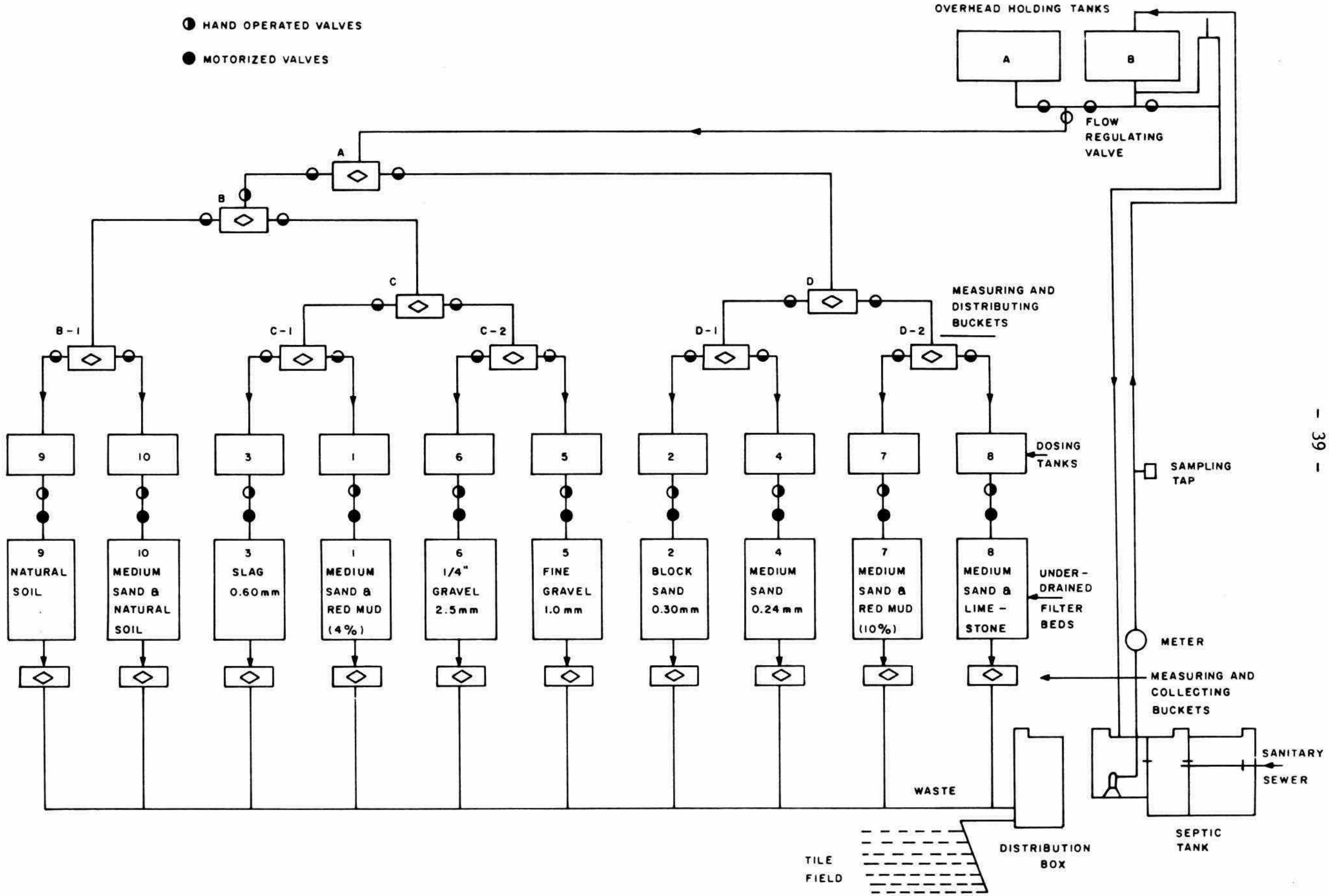
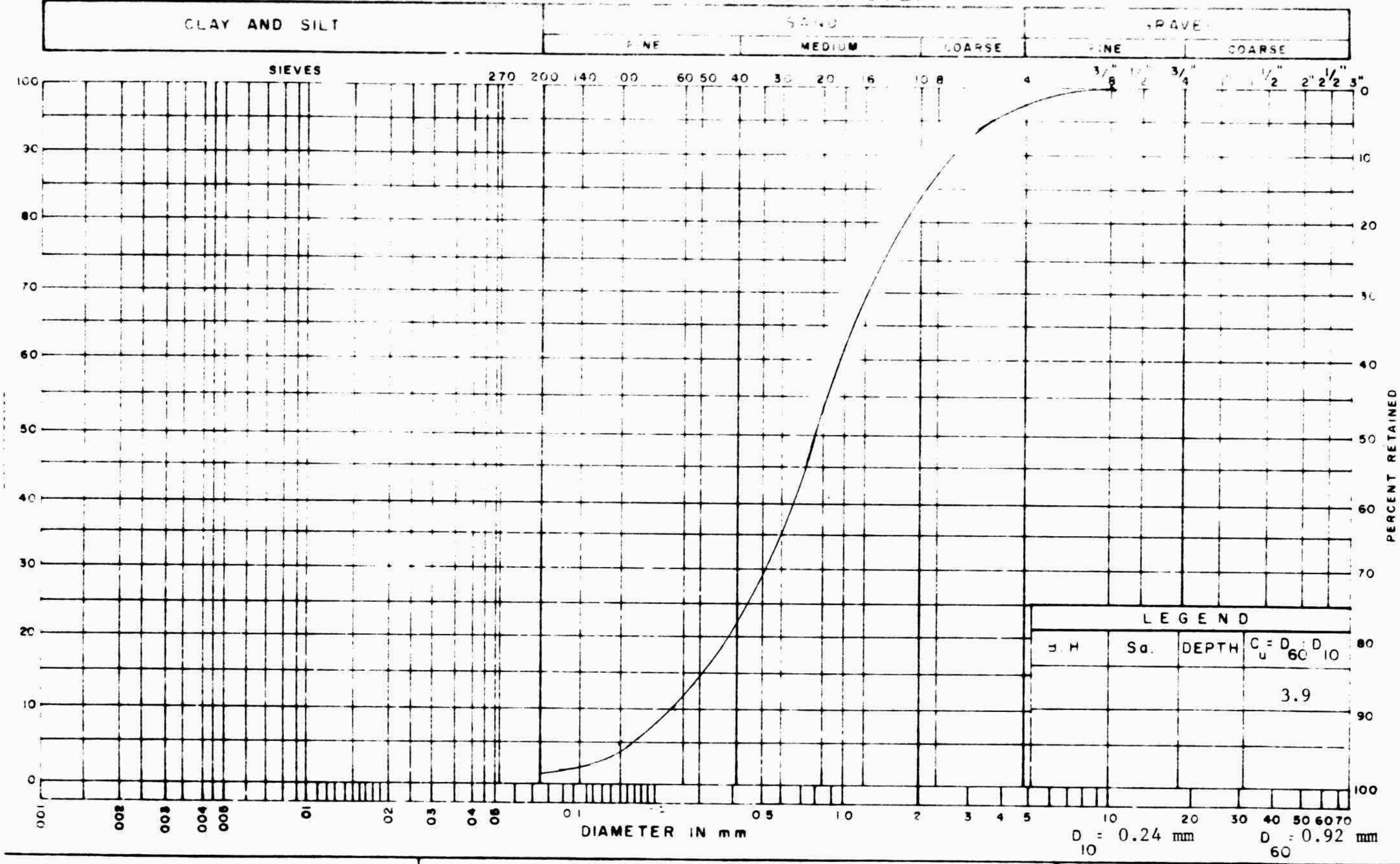


FIG. 2 SCHEMATIC FLOW SHEET



MINISTRY OF THE ENVIRONMENT

APPLIED SCIENCE SECTION

POLLUTION CONTROL BRANCH

GRAIN SIZE DISTRIBUTION

Fine to coarse Sand, traces of silt and fine gravel.

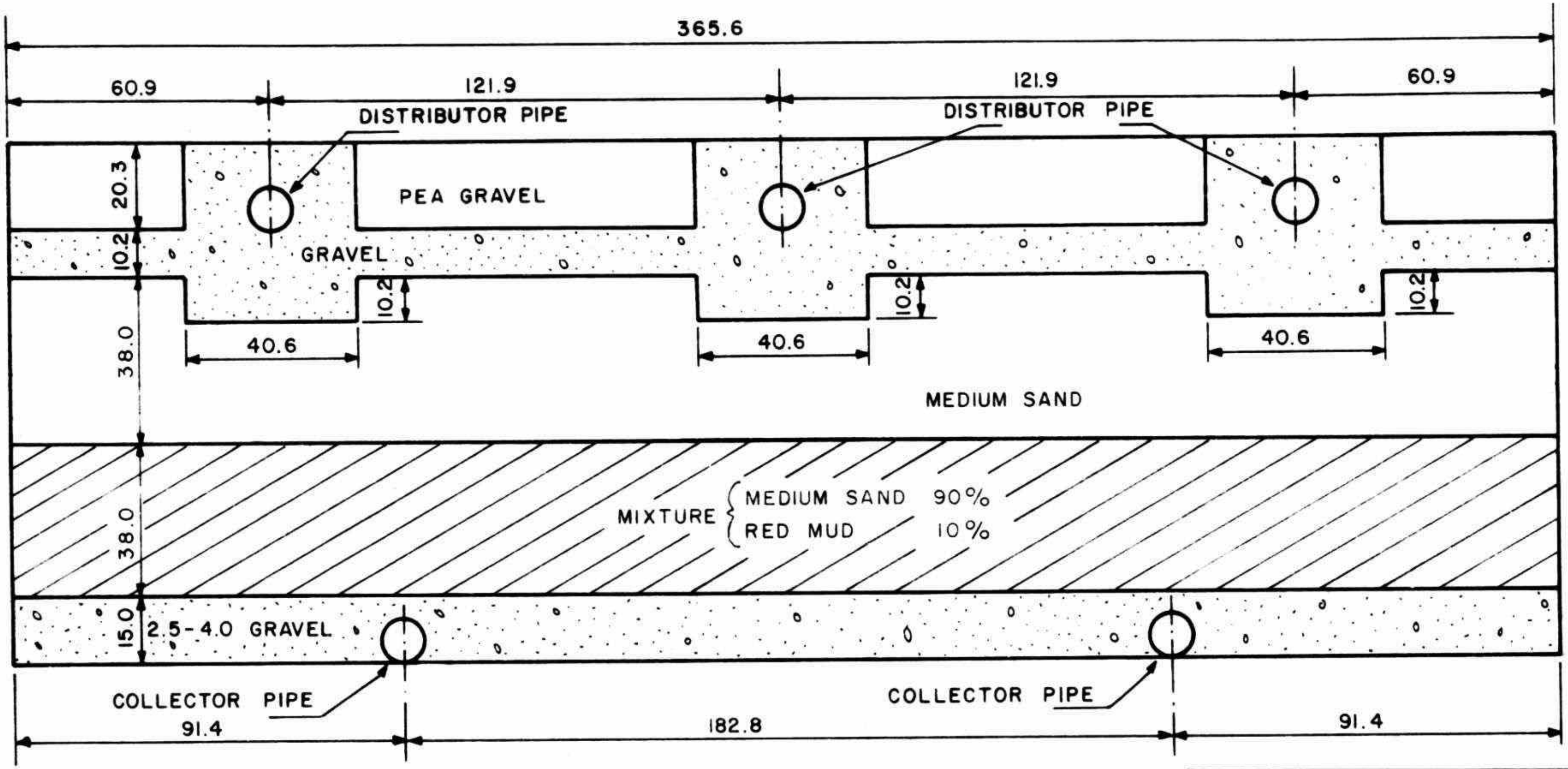
Figure 3

JOB N°

SITE Whitby

Bed No. 7

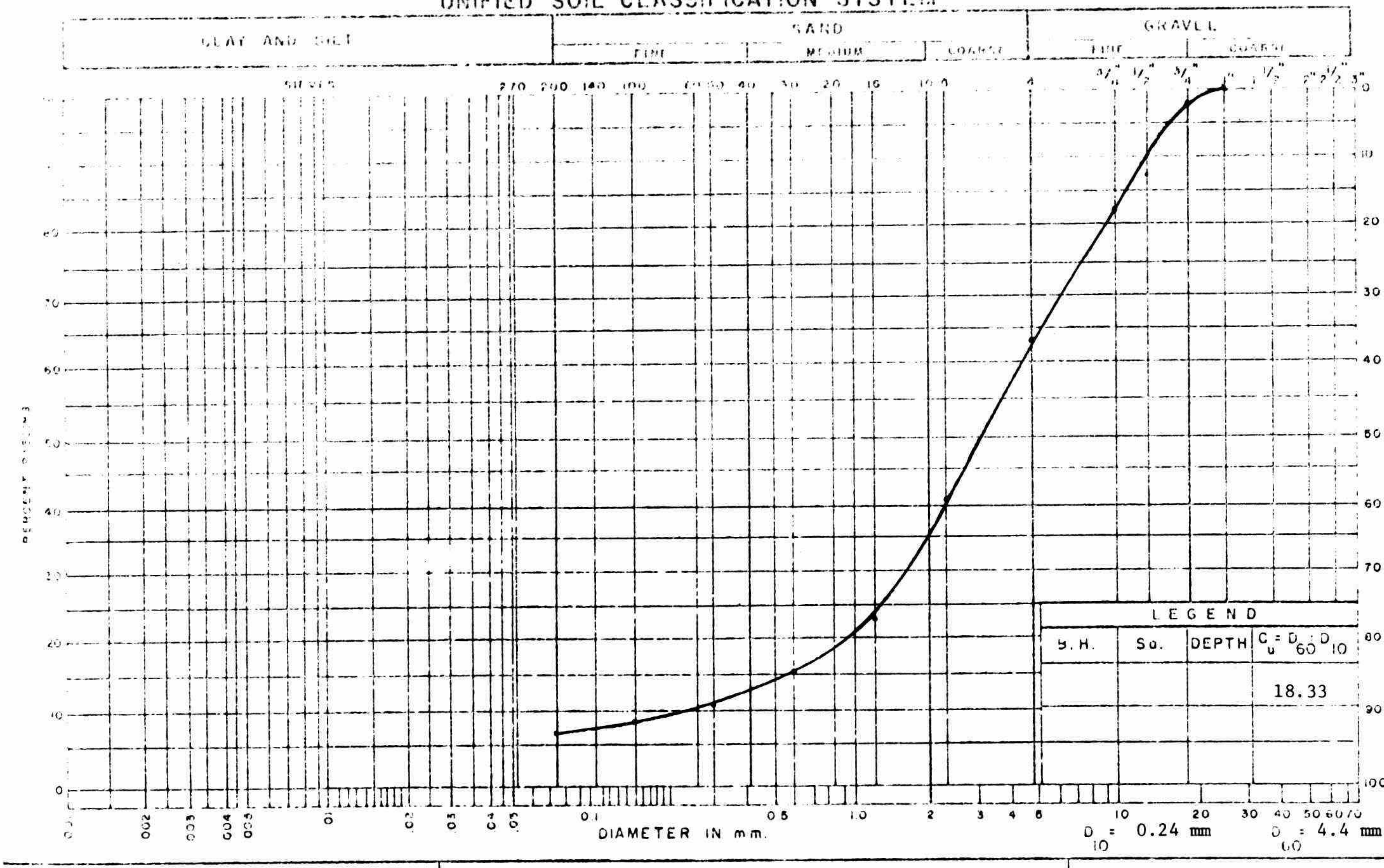
FIG. 4 — FILTER BED 7



NOT TO SCALE

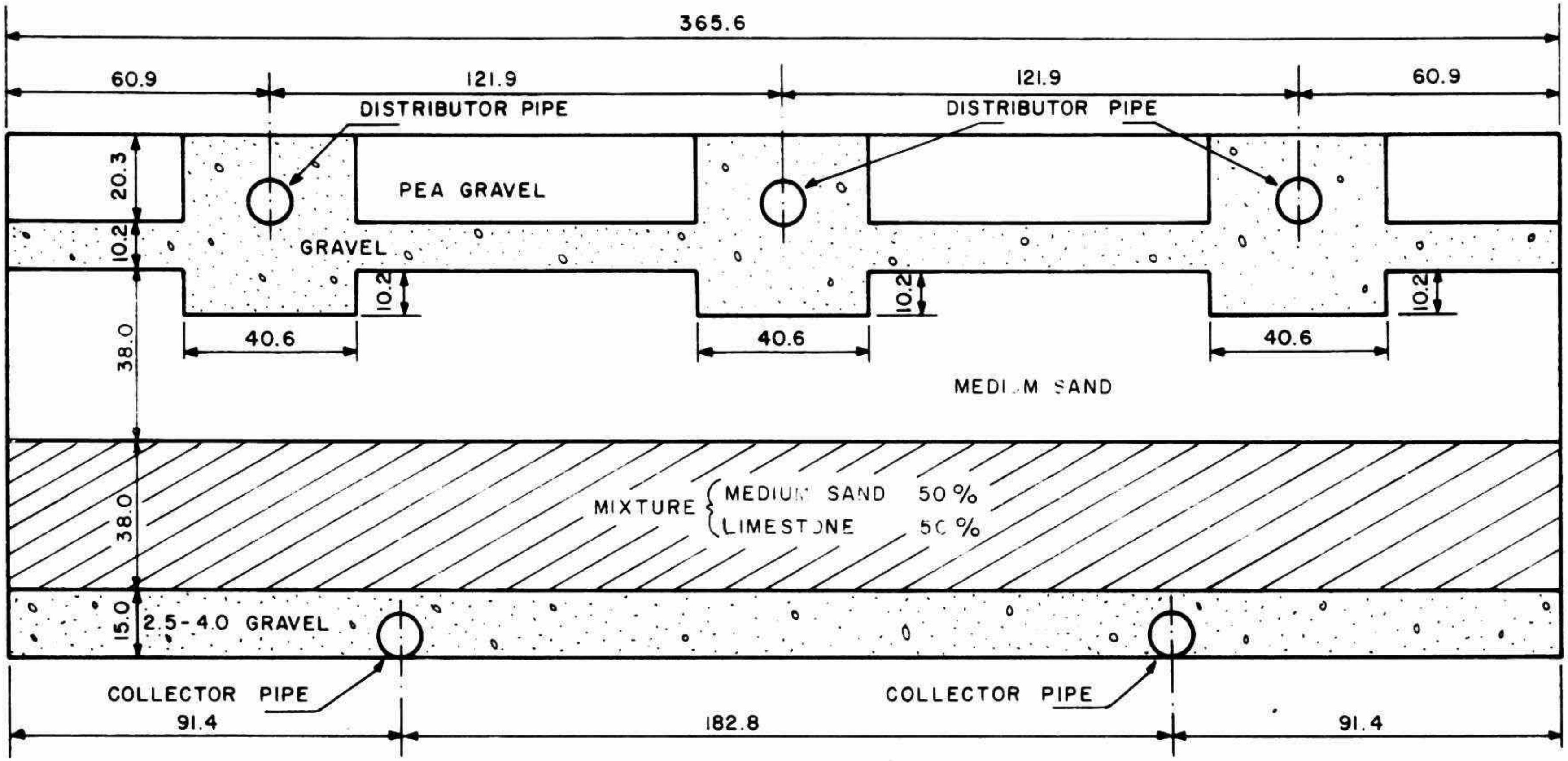
ALL MEASUREMENTS IN CENTIMETRES

MINISTRY OF THE ENVIRONMENT
POLLUTION CONTROL BRANCH
WHITBY EXPERIMENTAL STATION UNDERDRAINED FILTERS
DIAGRAM OF SECTION OF FILTER BED WITH MEDIUM SAND AND RED MUD
FEB. 1977



MINISTRY OF THE ENVIRONMENT	GRAIN SIZE DISTRIBUTION	JOB N° 73-4-1
APPLIED SCIENCE SECTION	Well graded curshed Limestone	SITE Limestone in Filter
POLLUTION CONTROL BRANCH	Figure 5	Bed No. 8

FIG. 6 - FILTER BED 8



NOT TO SCALE

ALL MEASUREMENTS IN CENTIMETRES

MINISTRY OF THE ENVIRONMENT

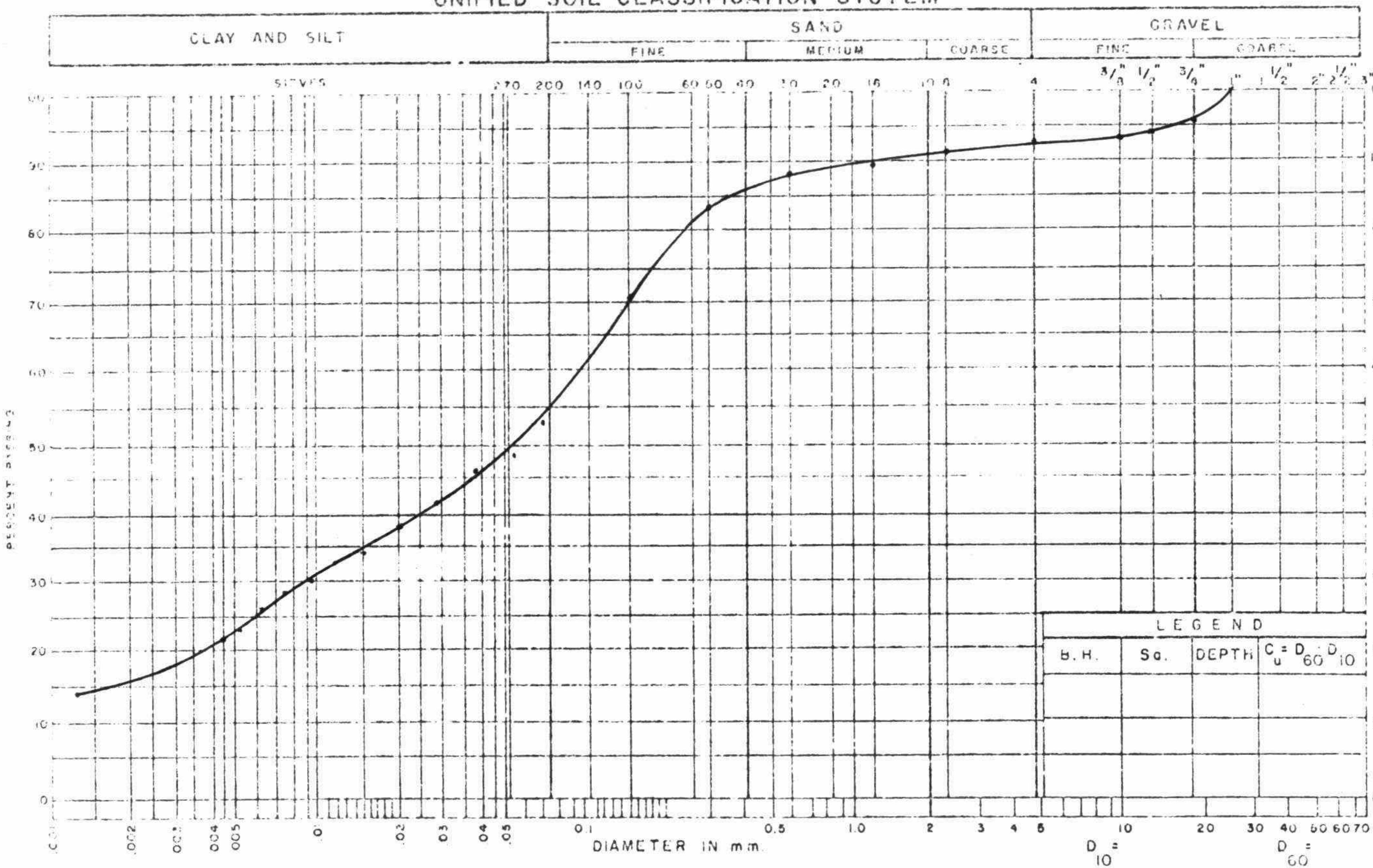
POLLUTION CONTROL BRANCH

WHITBY EXPERIMENTAL STATION
UNDERDRAINED FILTERS

DIAGRAM OF SECTION OF FILTER BED WITH MEDIUM SAND AND LIMESTONE

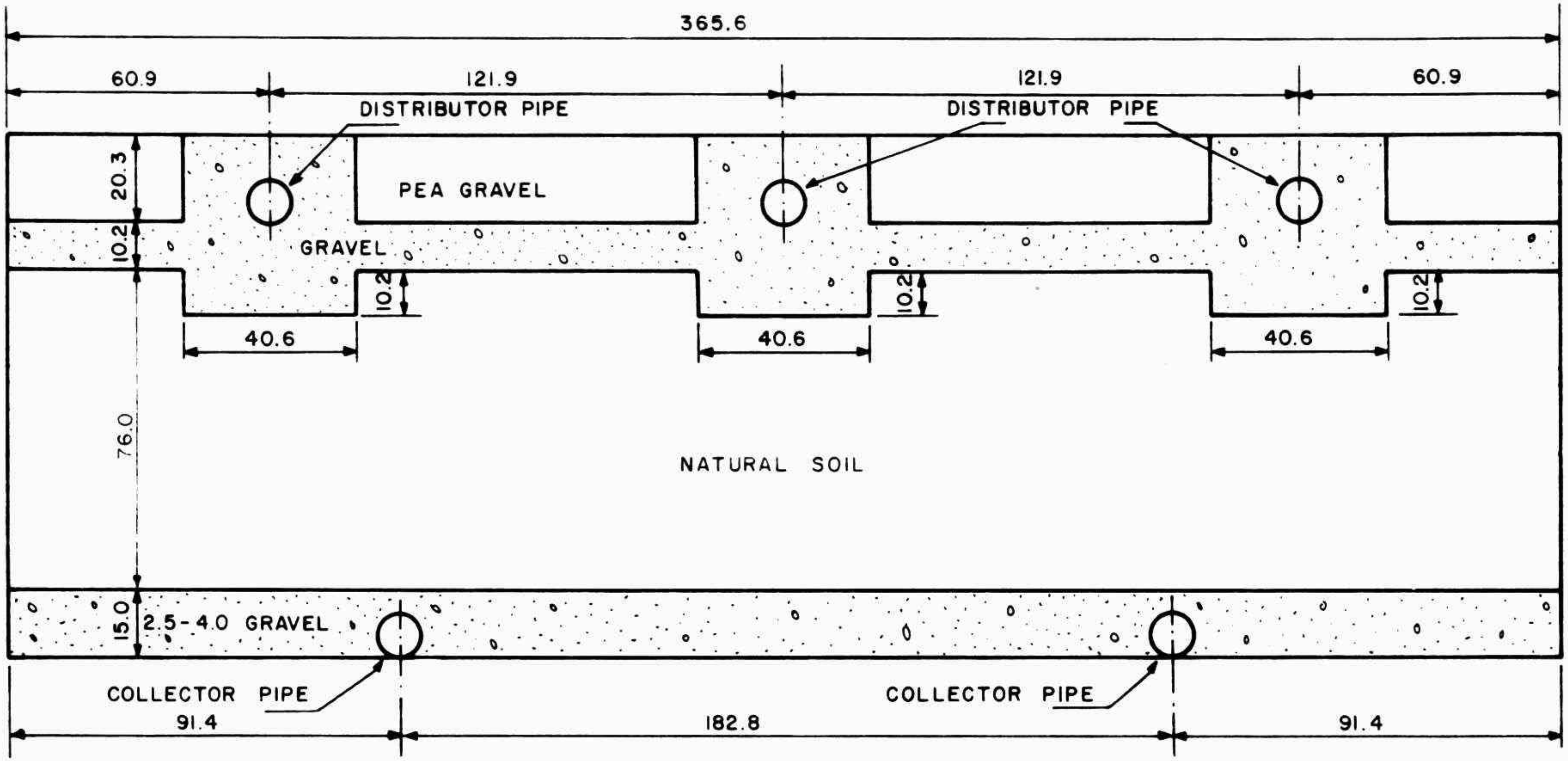
FEB. 1977

UNIFIED SOIL CLASSIFICATION SYSTEM



MINISTRY OF THE ENVIRONMENT APPLIED SCIENCE SECTION POLLUTION CONTROL BRANCH	GRAIN SIZE DISTRIBUTION Silt and Sand, some Clay, traces of Gravel Figure 7	JOB N° 74-4-1 SITE Natural soil in filter Bed No. 9

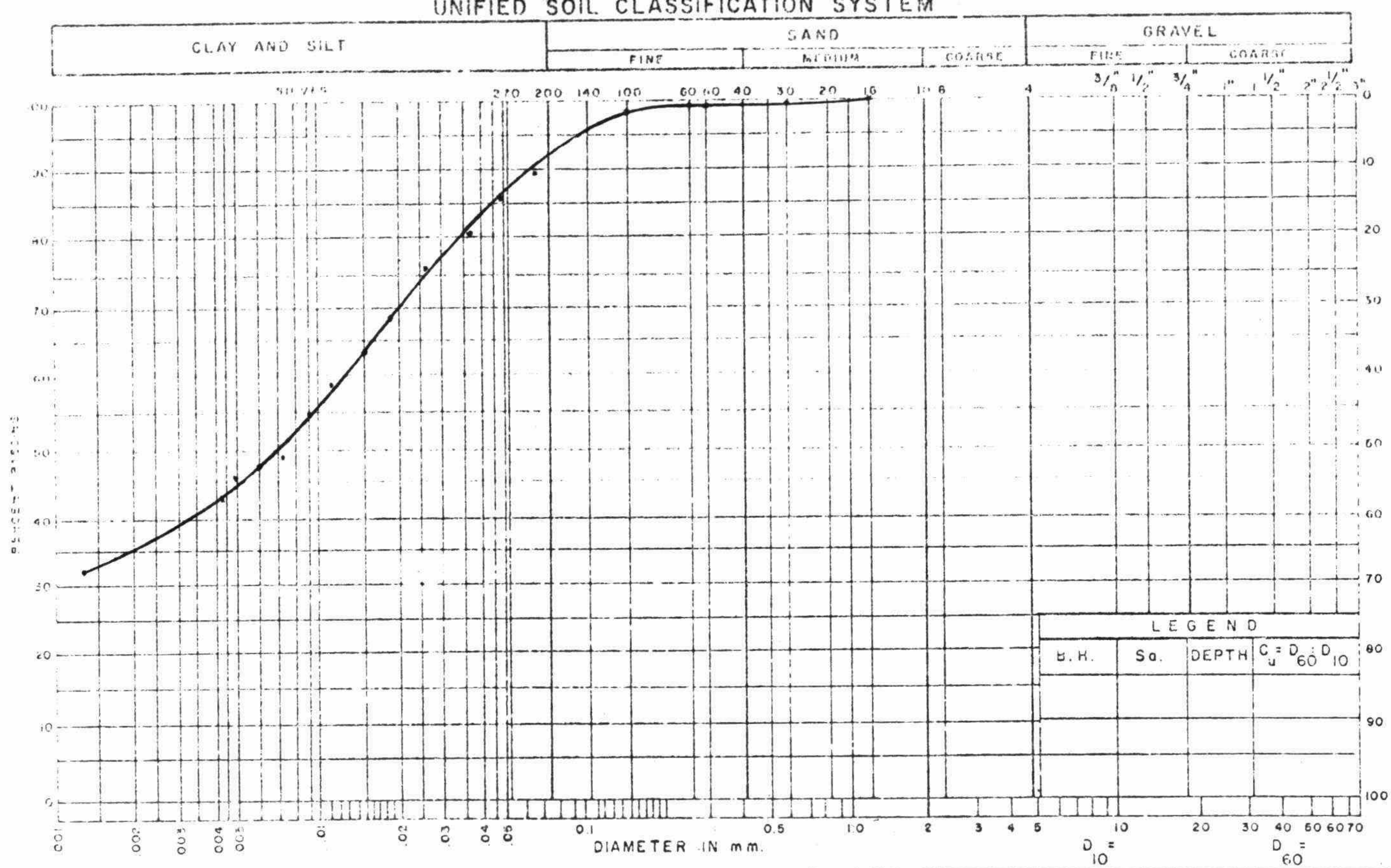
FIG. 8 — FILTER BED 9



NOT TO SCALE

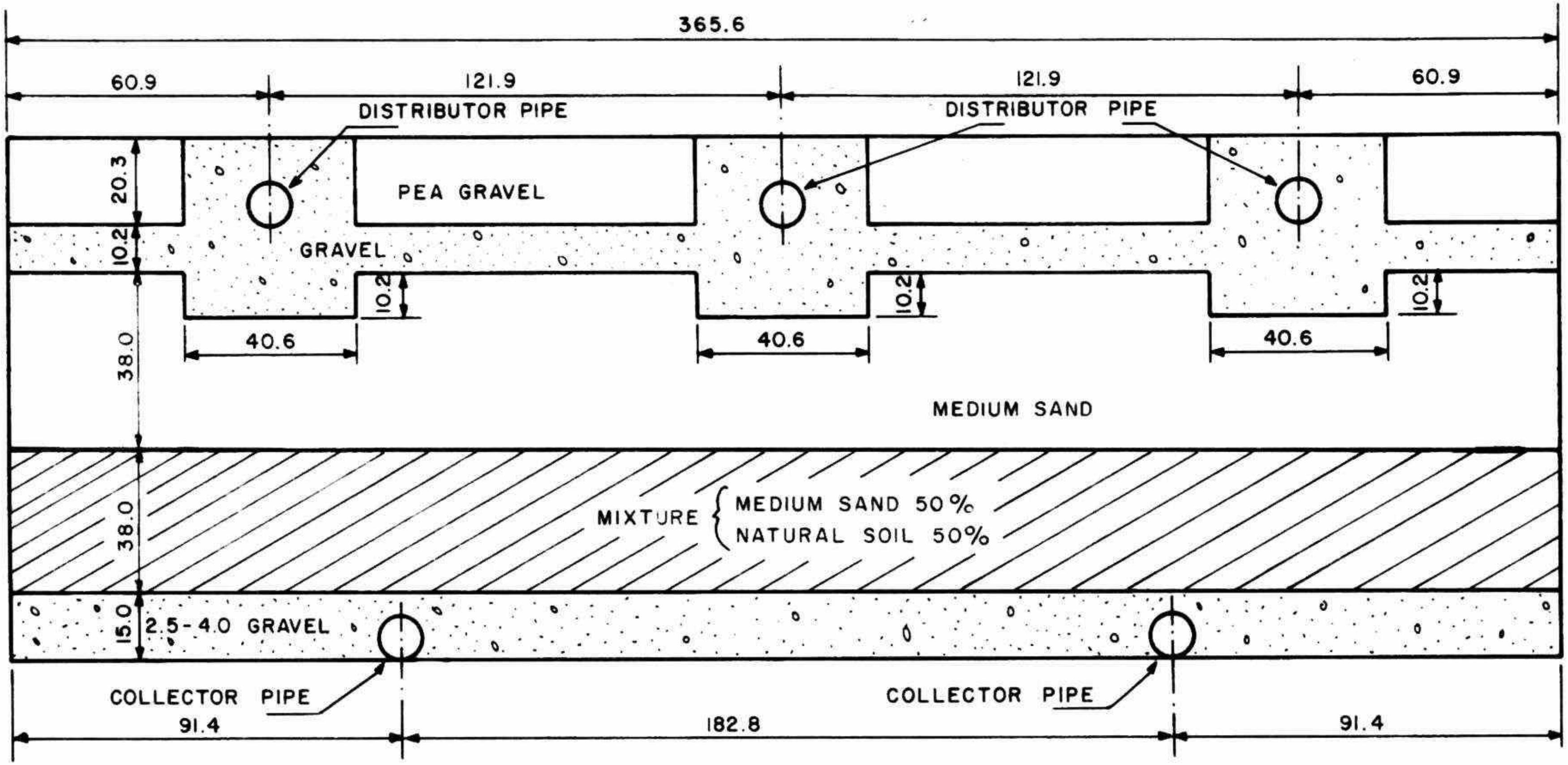
ALL MEASUREMENTS IN CENTIMETRES

MINISTRY OF THE ENVIRONMENT
POLLUTION CONTROL BRANCH
WHITBY EXPERIMENTAL STATION UNDERDRAINED FILTERS
DIAGRAM OF SECTION OF FILTER BED WITH NATURAL SOIL OBTAINED FROM SITE
FEB. 1977



MINISTRY OF THE ENVIRONMENT	GRAIN SIZE DISTRIBUTION	JOB Nº 73-3-1
APPLIED SCIENCE SECTION	Silt and Clay, traces of Sand	SITE Natural soil in filter
POLLUTION CONTROL BRANCH	Figure 9	Bed No. 10

FIG. 10 — FILTER BED 10



MINISTRY OF THE ENVIRONMENT

POLLUTION CONTROL BRANCH

WHITBY EXPERIMENTAL STATION
UNDERDRAINED FILTERS

DIAGRAM OF SECTION OF FILTER BED WITH MEDIUM SAND AND NATURAL SOIL FROM SITE

FEB. 1977

NOT TO SCALE

ALL MEASUREMENTS IN CENTIMETRES